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An Automatic Gore Panel Mapping System

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I. Introduction

The External Tank (ET), which supplies fuel for the main engines of the Space Shuttle, is comprised of three tanks: the oxygen, hydrogen, and inner tanks. The four domes which form the ends of the hydrogen and oxygen tanks are constructed by welding oblate, spheroidal metal sections called gore panels. These panels are chemically milled over large areas to lower the ET total weight. The weight of the raw material used to construct the oxygen and hydrogen tanks is 32,415 pounds. The final weight after chemical milling is 11,730 pounds, which is the result of a sixty-four percent weight reduction of the chem-milled parts. The Automatic Gore Mapping System is being developed to reduce the time and labor costs associated with manufacturing the External Tank. Presently, the chem-milled panels are manually scanned with an ultrasonic contact probe and mapped for thickness. The ultrasonic contact probe requires the application of couplant to the area of the part that is to be measured for thickness. To scan one panel manually during the entire production cycle requires an estimated 6.5 man days. Since chemical milling a gore panel is tedious and time consuming, NASA is funding a project that will automate this process. A workcell has been constructed at the Productivity Enhancement Facility at the Marshall Space Flight Center to develop a system that can scan the panels automatically. The automated system under development measures, stores, and computes the thickness of gore panels under computer control. As a result of the improved reliability of this system, the quality of the panels will be enhanced. This system is also being developed because of its potential applications of inspecting other manufactured parts.

II. Present Chem Milling Processes/Procedures

The stretch-formed panels are initially checked for visual damage, stamp approval, and material type. The severity of the lueder lines is also observed. Lueder lines are valleys and peaks that occur in the metal as a result of stretch-forming. Stretch-forming also causes the panels to be tapered - thicker on the ends than in the middle in an attempt to make the panel as uniform as possible. The panel is then cleaned and the rough areas are sanded and the gouge pits are filled. The panel is then chem milled once more to try to make it even more uniform. The panel is then cleaned with a tap rinse and a deoxidizing cleaning agent. The panel is manually sprayed with a green transparent maskant and allowed to cure for several hours. The panel is then placed into a template where the design for that particular panel is scribed. The design is scribed manually with a sharp blade. The maskant is then peeled from the area that is to be chem milled first. The panel is chem milled and then rinsed. The next section of maskant is removed and the panel is then chem milled and rinsed again. These steps are repeated until all the maskant is removed. A four inch grid is placed on the panel across the lueder lines. Using the grid, the panel is manually mapped for thickness. The thickness is measured ultrasonically with a point-to-point contact probe using water as couplant. The out-of-tolerance areas are outlined in 0.003 inch increments. The panel is then masked and cured again. The map lines are scribed and the highest area is peeled away. Three thousandths of an inch is chem milled from the exposed area. The panel is then cleaned and the next section of maskant is removed. Once again three thousandths of an inch is chem milled from the panel. The removal of three thousandths is done after each section of maskant is removed until all the maskant is gone. The panel then goes through its final inspection. The surface is checked for chem milled defects. The chem milled line configuration is also inspected.

III. The Automated Gore Mapping System

A robotic system, that will replace the present method of mapping gore panels, is presently under development at the Productivity Enhancement Facility at Marshall Space Flight Center. The funding for this system is provided by NASA. The system is comprised of a Cincinnati Milacron T3-776 robot, a Krautkramer-Branson WDM ultrasonic thickness measurement device, a Packard Bell AT computer, and an end-of-arm-tool. The key part of the system is the ultrasonic measurement device. This device can measure the thickness of gore panels with an accuracy of ± 0.01 inch. The sensor used with the device is a rubber-faced two-pieced transducer. A few drops of couplant is applied at the interface of the two pieces of the sensor. This supply of couplant will last several days. The sensor is installed on the end-of-arm-tool which is installed on the robot. The robot is an electrically driven, computer controlled, six axis, articulated arm.

The end-of-arm-tool (EOAT) consists of a rotating segment, retracting stem, microswitch, and an air cylinder. The rotating segment assures that the sensor is perpendicular to the panel. Four rubber stubs on the end of the segment press against the panel and four springs on the edge of the segment allow the semi-sphere segment to rotate. When the rotating segment is perpendicular, the stem of the EOAT retracts. The retracting allows for a microswitch to be triggered. The robot controller senses this signal, stops the robot, and then signals the robot to pop the sensor onto the panel. A 1.5 inch stroke, spring loaded, air cylinder is used to pop out the sensor. The Krautkramer-Branson emits a sound pulse a predetermined number of times. After this time period, if the Krautkramer-Branson does not lock onto a thickness reading, it signals the AT computer. In return the AT computer signals the robot controller to redo that particular point. At the next point, the process is repeated. After the gore panel has been completely scanned, a color-coded thickness contour of the out-of-tolerance regions on the panel can be generated and displayed on the AT computer. Three complete scans have been performed on one gore panel. All three scans are identical.

The Automatic Gore Mapping System has been simulated on a Silicon Graphics 3120 computer. The simulation of the system have been performed on Deneb's IGRIP and SILMA's Cimstation simulation packages. Using these packages, the most efficient workcell configuration can be obtained. The cycle time of the system can also be optimized. The packages also allow for less robot downtime, because the robot can remain in cycle while the operator sits in an office environment and simulates the workcell. The simulation is translated into robot code and then downloaded to the robot controller.

IV. FUTURE RESEARCH AND CONCLUSIONS

Further development of the Automatic Gore Mapping System is still in process. The down loading of the simulation of the system has to be performed to verify that the simulation package will translate the simulation code into robot code. Also a simulation of this system has to be programmed for a gantry robot instead of the articulating robot that is presently in the system. It was discovered using the simulation package that the articulation robot cannot reach all the points on some of the panels, therefore when the system is ready for production, a gantry robot will be used. Also a "hydrosensor" system is being developed to replace the point-to-point contact probe. The hydrosensor will allow the robot to perform a non-contact continuous scan of the panel. It will also provide a faster scan of the panel because it will eliminate the in-and-out movement required for the present end effector. The system software is currently being modified so that the hydrosensor will work with the system. The hydrosensor consists of a Krautkramer-Branson transducer encased in a plexiglass nozzle. The water stream pumped through the nozzle is the couplant for the probe. Also, software is being written so that the robot will have the ability to draw the contour lines on the panel displaying the out-of-tolerance regions. Presently the contour lines can only be displayed on the computer screen. Research is also being performed on improving and automating the method of scribing the panels. Presently the panels are manually scribed with a sharp knife. The use of a low power laser or water jet is being studied as a method of scribing the panels. The contour drawing pen will be replaced with scribing tool and the robot will then move along the contour lines. With these developments the Automatic Gore Mapping Systems will provide a reduction in time and labor costs associated with manufacturing the External Tank. The system also has the potential of inspecting other manufactured parts.

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VI. REFERENCES

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